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EDGE PRODUCT CORDIAL LABELING OF SWITCHING OPERATION ON SOME GRAPHS

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Abstract. Here we discuss and prove that the graphs attained by switching of any vertex with degree two which is adjacent to a vertex with degree two in triangular snake T_m, switching of any vertex with degree one in path P_m for $m \geq 3$ and m odd, Switching of vertex with degree two in P_m except vertices u_2 or u_{m-1} with $m > 4$ and switching of any vertex in cycle C_m are an edge product cordial graphs.

Keywords: Graph labeling, Product cordial labeling, Switching Operation, Edge Product Cordial Labeling.

AMS Subject Classification: 05C78.

1. Introduction

The graph labeling is an important area in graph theory which have many applications in the communication networks, coding theory, X-Ray Crystallography, chemistry, social sciences etc. there are several types of graph labelings available. For a study of various type of graph labeling we refer to Gallian [2].
Consider G as finite, simple and undirected graph with $U(G)$ as vertex set and and $F(G)$ as edge set, having no any vertex of degree zero. Let $|F(G)|$ and $|U(G)|$ be the number of edges and vertices of G respectively. We follow Gross and Yellen [1] for all other terminology. Cahit [3] in 1987, first established cordial labeling. Then after Sundaram et al.[4] presented Product cordial labeling. Barasara and Vaidya [5] have presented edge product cordial labeling in 2012. In 2013, Vaidya and Barasara [6] have discussed edge product cordial labeling in the context of some graph operation. In 2015, Thamizharasi and Rajeswari [10] have shown the existence of edge product cordial labeling for regular diagraph. In 2016, Prajapati and Patel [7] have discussed some results on edge product cordial labeling. in 2019, Prajapati and Patel [9] have discussed edge product cordial labeling of $W_n^{(t)}$, PS_n and DPS_n.

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Definition 1.1. *Let G be a graph with $U(G)$ as the vertex set and $F(G)$ as the edge set. Let $h : F(G) \to \{0,1\}$ be a function such that $|f_h(1) - f_h(0)| \le 1$, where $f_h(k) = |\{f \in F(G)|h(f) = k\}|$ for $k \in \{0,1\}$. Define the induced vertex labeling as*

$$h^*(u) = \prod_{j=1}^{m} h(f_j) \text{ for } \{u \in U(G), f_j \in F(G), f_j \text{ incident to } u\}.$$

If $|u_h(1) - u_h(0)| \le 1$, where $u_h(k) = |\{u \in U(G)|h^*(u) = k\}|$, for $k \in \{0,1\}$ then h is called an edge product cordial labeling.
A graph G which has an edge product cordial labeling is said to be an edge product cordial graph.

Definition 1.2. [8] *Graph derived by fetching a vertex u of G, eliminating all edges joining u to their adjacent vertices and by adding new edges joining u to their non-adjacent vertices in G is called vertex switching G_u of G.*

Definition 1.3. *Graph derived from path P_m by substituting every edge of P_m by C_3 is called Triangular Snake T_m .*

2. Main Results

Theorem 2.1. *The Graph derived from switching of any vertex in $C_m (m \ge 4)$ is an edge product cordial graph.*

Proof. Consider u_k for $1 \le k \le m$ are successive vertices of C_m. consider G_{u_1} is the graph derived from switching of a u_1 in C_m. So in G_{u_1} every vertex u_i other than u_2 and u_n is adjacent to u_1. Thus $|U(G_{u_1})| = m$ and $|F(G_{u_1})| = 2m - 5$. Define $h : F(G_{u_1}) \to \{0,1\}$ as:

$$h(f) = \begin{cases} 1 & \text{if } f = u_k u_{k+1} \text{ for } 2 \le k \le \lfloor \frac{m}{2} \rfloor; \\ 0 & \text{if } f = u_k u_{k+1} \text{ for } \lfloor \frac{m}{2} \rfloor + 1 \le k \le m-2; \\ 1 & \text{if } f = u_1 u_k \text{ for } 3 \le k \le \lceil \frac{m}{2} \rceil; \\ 0 & \text{if } f = u_1 u_k \text{ for } \lceil \frac{m}{2} \rceil + 1 \le k \le m-1; \\ 1 & \text{if } f = u_m u_{m-1}. \end{cases}$$

Thus $h^* : U(G_{u_1}) \to \{0,1\}$ is,

$$\begin{aligned} h^*(u_1) &= \prod_{k=3}^{m-1} h(u_1 u_k) = 0, \\ h^*(u_2) &= h(u_2 u_3) = 1, \\ h^*(u_m) &= h(u_m u_{m-1}) = 1, \\ h^*(u_k) &= h(u_k u_{k-1}) h(u_k u_{k+1}) h(u_k u_1) = 1 \quad \text{for } 3 \le k \le \left\lfloor \frac{m}{2} \right\rfloor, \\ h^*(u_k) &= h(u_k u_{k-1}) h(u_k u_{k+1}) h(u_k u_1) = 0 \quad \text{for } \left\lfloor \frac{m}{2} \right\rfloor + 1 \le k \le m-1. \end{aligned}$$

Hence, $u_h(1) = \left| \left\{ u_2, u_3, \dots, u_{\lfloor \frac{m}{2} \rfloor}, u_m \right\} \right|$ and $u_h(0) = \left| \left\{ u_1, u_{\lfloor \frac{m}{2} \rfloor + 1}, u_{\lfloor \frac{m}{2} \rfloor + 2}, \dots, u_{m-1} \right\} \right|$. So $u_h(0) = \left\lceil \frac{m}{2} \right\rceil$, $u_h(1) = \left\lfloor \frac{m}{2} \right\rfloor$ and $f_h(0) = \left\lfloor \frac{2m-5}{2} \right\rfloor$, $f_h(1) = \left\lceil \frac{2m-5}{2} \right\rceil$. Thus $|u_h(0) - u_h(1)| = 1 \le 1$ and $|f_h(0) - f_h(1)| = 1 \le 1$. Hence G_{u_1} is an edge product cordial graph. □

Example 2.1. *Edge product cordial labeling of G_{u_1} derived from C_9 reveal in the following figure 1.*

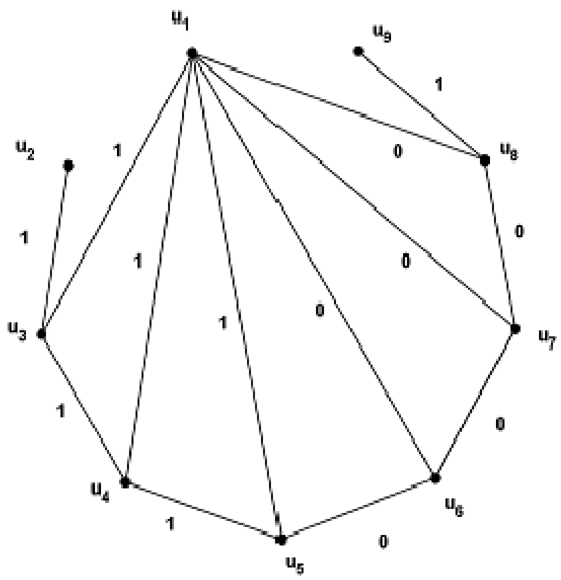

FIGURE 1. Graph G_{u_1} derived from C_9

Theorem 2.2. *The graph derived from switching of a vertex with degree one in P_m is an edge product cordial graph if and only if $m \geq 3$ and m odd.*

Proof. Consider u_k for $1 \leq k \leq m$ are successive vertices of path P_m. Let G_{u_1} be the graph derived by switching of a vertex with degree one say u_1 of P_m. So in G_{u_1}, every vertex u_k for $k = 3, 4, \ldots, m$ is adjacent to u_1. Thus $|U(G_{u_1})| = m$ and $|F(G_{u_1})| = 2m - 4$. Here we cosider two cases:
Case 1 If $m > 4$ then define $h : F(G_{u_1}) \to \{0, 1\}$ as:

$$h(f) = \begin{cases} 1 & \text{if } f = u_k u_{k+1} \text{ for } 2 \leq k \leq \lceil \frac{m}{2} \rceil; \\ 0 & \text{if } f = u_k u_{k+1} \text{ for } \lceil \frac{m}{2} \rceil + 1 \leq k \leq m - 1; \\ 1 & \text{if } f = u_1 u_k \text{ for } 3 \leq k \leq \lceil \frac{m}{2} \rceil; \\ 0 & \text{if } f = u_1 u_k \text{ for } \lceil \frac{m}{2} \rceil + 1 \leq k \leq m. \end{cases}$$

Thus h^* is given by,

$$h^*(u_1) = \prod_{k=3}^{m} h(u_1 u_k) = 0,$$
$$h^*(u_2) = h(u_2 u_3) = 1,$$
$$h^*(u_n) = h(u_1 u_m) h(u_m u_{m-1}) = 0,$$
$$h^*(u_k) = h(u_k u_{k-1}) h(u_k u_{k+1}) h(u_k u_1) = 1 \quad \text{for } 3 \leq k \leq \left\lceil \frac{m}{2} \right\rceil,$$
$$h^*(u_k) = h(u_k u_{k-1}) h(u_k u_{k+1}) h(u_k u_1) = 0 \quad \text{for } \left\lceil \frac{m}{2} \right\rceil + 1 \leq k \leq m - 1.$$

Hence, $u_h(1) = \left|\left\{u_2, u_3, \ldots, u_{\lceil \frac{m}{2} \rceil}\right\}\right|$ and $u_h(0) = \left|\left\{u_1, u_{\lceil \frac{m}{2} \rceil+1}, u_{\lceil \frac{m}{2} \rceil+2}, \ldots, u_{m-1}, u_m\right\}\right|$.
So $u_h(0) = \left\lceil \frac{m}{2} \right\rceil$, $u_h(1) = \left\lfloor \frac{m}{2} \right\rfloor$ and $f_h(0) = f_h(1) = \left\lfloor \frac{2m-4}{2} \right\rfloor$.
Case 2: For $m = 3$, labeling is shown in the figure 2.
Hence $|u_h(0) - u_h(1)| = 1 \leq 1$ and $|f_h(0) - f_h(1)| = 0 \leq 1$. So G_{u_1} is an edge product cordial graph.

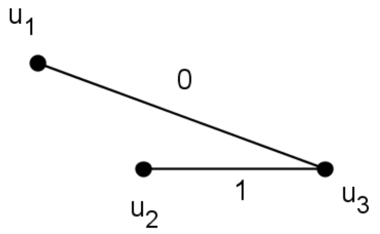

FIGURE 2. G_{u_1} derived from P_3

□

Example 2.2. *Edge product cordial labeling of G_{u_1} derived from P_7 reveal in the following figure 3.*

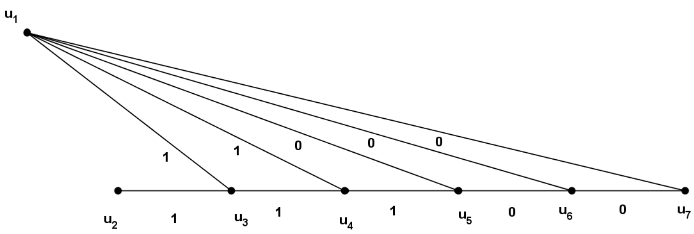

FIGURE 3. G_{u_1} derived from P_7

Theorem 2.3. *The graph derived from switching of a vertex with degree two in P_m except u_2 or u_{m-1} with $m > 4$ is an edge product cordial graph.*

Proof. Consider u_k for $1 \leq k \leq m$ are successive vertices of path P_m. Let G_{u_i}, $3 \leq i \leq m-2$ be the graph derived by switching of a vertex u_i. So in G_{u_i}, every vertex u_k for $1 \leq k \leq m$ and $k \neq i-1, i+1, i$ is adjacent to u_i. Thus $|U(G_{u_i})| = m$ and $|F(G_{u_i})| = 2m - 6$. To prove this theoram we will cosider the case for switching of vertex u_i, $3 \leq i \leq \lceil \frac{m}{2} \rceil$. For rest of the vertices u_i, $\lceil \frac{m}{2} \rceil + 1 \leq i \leq m-3$ proof is similar. Define $h : F(G_{u_i}) \to \{0, 1\}$ as:

$$h(f) = \begin{cases} 1 & \text{if } \; f = u_i u_k \; \text{ for } \; 3 \leq i \leq \lceil \frac{m}{2} \rceil, k < i-1 \; \text{ and } \; i+1 < k \leq \lceil \frac{m}{2} \rceil + 1; \\ 0 & \text{if } \; f = u_i u_k \; \text{ for } \; 3 \leq i \leq \lceil \frac{m}{2} \rceil, \lceil \frac{m}{2} \rceil + 1 < k \leq m; \\ 1 & \text{if } \; f = u_k u_{k+1} \; \text{ for } \; 1 \leq k < i-1, \; i+1 \leq k \leq \lfloor \frac{m}{2} \rfloor + 1; \\ 0 & \text{if } \; f = u_k u_{k+1} \; \text{ for } \; \lfloor \frac{m}{2} \rfloor + 1 < k \leq m. \end{cases}$$

Thus h^* is given by,

$$h^*(u_i) = \prod_{\substack{k=1 \\ k\neq i-1,i,i+1}}^{m} h(u_iu_k) = 0,$$
$$h^*(u_1) = h(u_1u_i)h(u_1u_2) = 1,$$
$$h^*(u_{i-1}) = h(u_{i-1}u_{i-2}) = 1,$$
$$h^*(u_{i+1} = \begin{cases} h(u_{i+1}u_{i+2}) = 0 \text{ for } m \text{ odd and } i = \left\lceil \frac{m}{2} \right\rceil, \\ h(u_{i+1}u_{i+2}) = 1; \text{ otherwise,} \end{cases}$$
$$h^*(u_m) = h(u_iu_m)h(u_mu_{m-1}) = 0,$$
$$h^*(u_k) = h(u_ku_{k-1})h(u_ku_{k+1})h(u_ku_i) = 1 \quad \text{for } 2 \leq k \leq i-2,$$
$$h^*(u_k) = h(u_ku_{k-1})h(u_ku_{k+1})h(u_ku_i) = 1 \quad \text{for } i+2 \leq k \left\lfloor \frac{m}{2} \right\rfloor + 1,$$
$$h^*(u_k) = h(u_ku_{k-1})h(u_ku_{k+1})h(u_ku_i) = 0 \quad \text{for } \left\lfloor \frac{m}{2} \right\rfloor + 2 \leq k \leq m-1.$$

Hence,

$$u_h(1) = \begin{cases} \left| \{u_1, u_2, \ldots, u_{i-1}\} \right|; \ i = \left\lceil \frac{m}{2} \right\rceil \text{ and } m \text{ odd;} \\ \left| \left\{u_1, u_2, \ldots, u_{i-1}, u_{i+1}, u_{i+2}, \ldots, u_{\lfloor \frac{m}{2} \rfloor + 1}\right\} \right|; \text{ otherwise.} \end{cases}$$

$$u_h(0) = \begin{cases} \left| \{u_i, u_{i+1}, u_{i+2}, \ldots, u_m\} \right|; \ i = \left\lceil \frac{m}{2} \right\rceil \text{ and } m \text{ odd;} \\ \left| \left\{u_i, u_{\lfloor \frac{m}{2} \rfloor + 2}, u_{\lceil \frac{m}{2} \rceil + 3}, \ldots, u_m\right\} \right|; \text{ otherwise.} \end{cases}$$

$u_h(1) = \left| \left\{u_1, u_2, \ldots, u_{i-1}, u_{i+1}, u_{i+2}, \ldots, u_{\lfloor \frac{m}{2} \rfloor + 1}; i \neq \left\lceil \frac{m}{2} \right\rceil \text{ and } m \text{ odd}\right\} \right|$ and $u_h(0) = \left| \left\{u_i, u_{\lfloor \frac{m}{2} \rfloor + 2}, u_{\lceil \frac{m}{2} \rceil + 3}, \ldots, u_m\right\} \right|$. So $u_h(0) = \left\lceil \frac{m}{2} \right\rceil$, $u_h(1) = \left\lfloor \frac{m}{2} \right\rfloor$ and $f_h(0) = f_h(1) = \left\lfloor \frac{2m-6}{2} \right\rfloor$. Hence $|u_h(0) - u_h(1)| = 1 \leq 1$ and $|f_h(0) - f_h(1)| = 0 \leq 1$. So G_{u_1} is an edge product cordial graph. □

Example 2.3. *Edge product cordial labeling of G_{u_5} derived from P_{11} reveal in the following figure 4.*

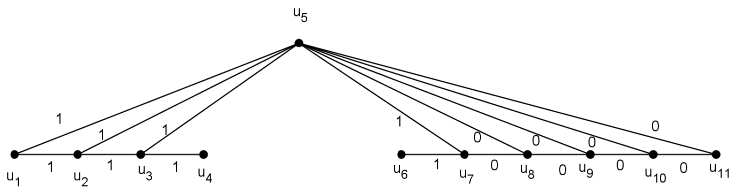

FIGURE 4. G_{u_5} derived from P_{11}

Theorem 2.4. *The graph derived from switching of a vertex with degree two which is adjacent to a vertex with degree two in triangular snake T_m is an edge product cordial graph.*

Proof. Consider u_k for $1 \le k \le m$ are the successive vertices of P_m. Let $w_1, w_2, \ldots, w_{m-1}$ be the vertices of triangle other than the vertices of P_m in T_m. Consider G_w graph derived by switching of any vertex with degree two which is adjacent to a vertex with degree two in T_m. Thus $|U(G_w)| = 2m-1$ and $|F(G_w)| = 5m-9$. Then there are four cases arise:
Case 1 If $w = w_1$, then in G_{w_1}, every vertex w_k for $k = 2, 3, \ldots, m-1$ and u_k for $k = 3, 4, \ldots, m$ are adjacent to w_1. Define mapping $r : F(G_{w_1}) \to \{0,1\}$ by,

$$r(f) = \begin{cases} 1 & \text{if} \quad f = u_k u_{k+1} \quad \text{for} \quad 1 \le k \le \left\lceil \frac{m}{2} \right\rceil; \\ 0 & \text{if} \quad f = u_k u_{k+1} \quad \text{for} \quad \left\lceil \frac{m}{2} \right\rceil + 1 \le k \le m-1; \\ 1 & \text{if} \quad f = w_1 u_k \quad \text{for} \quad 3 \le k \le \left\lceil \frac{m}{2} \right\rceil; \\ 0 & \text{if} \quad f = w_1 u_k \quad \text{for} \quad \left\lceil \frac{m}{2} \right\rceil + 1 \le k \le m; \\ 1 & \text{if} \quad f \in \{w_1 w_k, w_k u_{k+1}\} \quad \text{for} \quad 2 \le k \le \left\lfloor \frac{m}{2} \right\rfloor; \\ 0 & \text{if} \quad f \in \{w_1 w_k, w_k u_{k+1}\} \quad \text{for} \quad \left\lfloor \frac{m}{2} \right\rfloor + 1 \le k \le m-1; \\ 1 & \text{if} \quad f = w_k u_k \quad \text{for} \quad 2 \le k \le \left\lceil \frac{m}{2} \right\rceil; \\ 0 & \text{if} \quad f = w_k u_k \quad \text{for} \quad \left\lceil \frac{m}{2} \right\rceil + 1 \le k \le m-1. \end{cases}$$

Thus $r^* : U(G_{w_1}) \to \{0,1\}$ is obtained as follows,

$$\begin{aligned}
r^*(w_1) &= \prod_{k=3}^{m} r(w_1 u_k) \prod_{k=2}^{m-1} r(w_1 w_k) = 0, \\
r^*(w_k) &= r(w_k u_k) r(w_k u_{k+1}) r(w_1 w_k) = 1 \quad \text{for } 2 \le k \le \left\lfloor \frac{m}{2} \right\rfloor, \\
r^*(w_k) &= r(w_k u_k) r(w_k u_{k+1}) r(w_1 w_k) = 0 \ \text{ for } \left\lfloor \frac{m}{2} \right\rfloor + 1 \le k \le m-1, \\
r^*(u_1) &= r(u_1 u_2) = 1, \\
r^*(u_2) &= r(u_1 u_2) r(u_2 u_3) r(w_2 u_2) = 1, \\
r^*(u_k) &= r(u_k u_{k-1}) r(u_k u_{k+1}) r(w_{k-1} u_k) r(w_k u_k) r(w_1 u_k) = 1 \quad \text{for } 3 \le k \le \left\lceil \frac{m}{2} \right\rceil, \\
r^*(u_k) &= r(u_k u_{k-1}) r(u_k u_{k+1}) r(u_k w_{k-1}) r(w_k u_k) r(w_1 u_k) = 0 \ \text{ for } \left\lceil \frac{m}{2} \right\rceil + 1 \le k \le m-1, \\
r^*(u_m) &= r(u_{m-1} u_m) r(w_{m-1} u_m) r(w_1 u_m) = 0.
\end{aligned}$$

Hence, $u_r(1) = \left| \left\{ u_1, u_2, \ldots, u_{\lceil \frac{m}{2} \rceil}, w_2, w_3, \ldots, w_{\lfloor \frac{m}{2} \rfloor} \right\} \right|$ and
$u_r(0) = \left| \left\{ u_{\lceil \frac{m}{2} \rceil + 1}, u_{\lceil \frac{m}{2} \rceil + 2}, \ldots, u_m, w_1, w_{\lfloor \frac{m}{2} \rfloor} + 1, w_{\lfloor \frac{m}{2} \rfloor} + 2, \ldots, w_{m-1} \right\} \right|$.
So $u_r(0) = u_r(1) + 1 = m$ and $f_r(1) = \left\lfloor \frac{5m-9}{2} \right\rfloor$, $f_r(0) = \left\lceil \frac{5m-9}{2} \right\rceil$.

If $w = w_m$, then proof is similar.
Case 2 If $w = u_1$, then in G_{u_1}, every vertex u_k for $3 \le k \le m$ and w_k for $2 \le k \le m-1$

are adjacent to u_1. Define mapping $r : F(G_{u_1}) \to \{0,1\}$ by,

$$r(f) = \begin{cases} 1 & \text{if} \quad f \in \{u_k u_{k+1}, w_k u_k\} \quad \text{for} \quad 2 \le k \le \lceil \frac{m}{2} \rceil ; \\ 0 & \text{if} \quad f \in \{u_k u_{k+1}, w_k u_k\} \quad \text{for} \quad \lceil \frac{m}{2} \rceil + 1 \le k \le m-1; \\ 1 & \text{if} \quad f = u_1 w_k \quad \text{for} \quad 2 \le k \le \lfloor \frac{m}{2} \rfloor ; \\ 0 & \text{if} \quad f = u_1 w_k \quad \text{for} \quad \lfloor \frac{m}{2} \rfloor + 1 \le k \le m-1; \\ 1 & \text{if} \quad f = u_1 u_k \quad \text{for} \quad 3 \le k \le \lceil \frac{m}{2} \rceil ; \\ 0 & \text{if} \quad f = u_1 u_k \quad \text{for} \quad \lceil \frac{m}{2} \rceil + 1 \le k \le m; \\ 1 & \text{if} \quad f = w_k u_{k+1} \quad \text{for} \quad 1 \le k \le \lfloor \frac{m}{2} \rfloor ; \\ 0 & \text{if} \quad f = w_k u_{k+1} \quad \text{for} \quad \lfloor \frac{m}{2} \rfloor + 1 \le k \le m-1. \end{cases}$$

Thus $r^* : U(G_{u_1}) \to \{0,1\}$ is obtained as follows,

$r^*(w_1) = r(w_1 u_2) = 1,$

$r^*(w_k) = r(w_k u_k) r(w_k u_{k+1}) r(u_1 w_k) = 1 \text{ for } 2 \le k \le \left\lfloor \dfrac{m}{2} \right\rfloor,$

$r^*(w_k) = r(w_i u_k) r(w_k u_{k+1}) r(u_1 w_k) = 0 \quad \text{for} \quad \left\lfloor \dfrac{m}{2} \right\rfloor + 1 \le k \le m-1,$

$r^*(u_2) = r(w_1 u_2) r(w_2 u_2) r(u_2 u_3) = 1,$

$r^*(u_1) = \displaystyle\prod_{k=2}^{m-1} r(u_1 w_k) \prod_{k=3}^{m} r(u_1 u_k) = 0,$

$r^*(u_k) = r(u_k w_{k-1}) r(u_k w_k) r(u_{k-1} u_k) r(u_k u_{k+1}) r(u_1 u_k) = 1 \quad \text{for } 3 \le k \le \left\lceil \dfrac{m}{2} \right\rceil,$

$r^*(u_k) = r(u_k w_{k-1}) r(u_k w_k) r(u_{k-1} u_k) r(u_k u_{k+1}) r(u_1 u_k) = 0 \quad \text{for} \quad \left\lceil \dfrac{m}{2} \right\rceil + 1 \le k \le m-1,$

$r^*(u_m) = r(w_{m-1} u_m) r(u_{m-1} u_m) r(u_1 u_m) = 0.$

Hence, $u_r(1) = \left| \left\{ u_1, u_2, \ldots, u_{\lceil \frac{m}{2} \rceil}, w_2, w_3, \ldots, w_{\lfloor \frac{m}{2} \rfloor} \right\} \right|$ and

$u_r(0) = \left| \left\{ u_{\lceil \frac{m}{2} \rceil + 1}, u_{\lceil \frac{m}{2} \rceil + 2}, \ldots, u_m, w_1, w_{\lfloor \frac{m}{2} \rfloor + 1}, w_{\lfloor \frac{m}{2} \rfloor + 2}, \ldots, w_{m-1} \right\} \right|.$

So $u_r(0) = u_r(1) + 1 = m$ and $f_r(1) = \left\lfloor \dfrac{5m-9}{2} \right\rfloor, f_r(0) = \left\lceil \dfrac{5m-9}{2} \right\rceil.$

If $w = u_m$, then proof is similar.

Thus from the aboves cases $|u_h(0) - u_h(1)| = 1 \le 1$ and $|f_h(0) - f_h(1)| = 1 \le 1$. Hence G_w is an edge product cordial graph. □

Example 2.4. *Edge product cordial labeling of G_{w_1} derived by T_6 and G_{u_1} obtained by T_7 shown in the following figure 5 and figure 6 respectively.*

3. Conclusions

We examine four results on graph derived by a vertex switching with degree one in P_m if and only if $m \ge 3$ and m is odd, Switching of vertex with degree two in P_m except u_2 or u_{m-1} with $m > 4$, switching of any vertex in C_m and a vertx switching with degree two which is adjacent to a vertex with degree two in T_m are edge product cordial graph.

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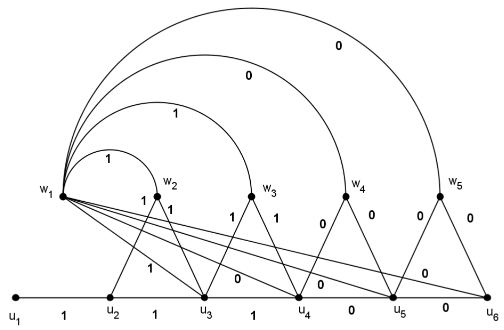

FIGURE 5. G_{w_1} obtained from T_6

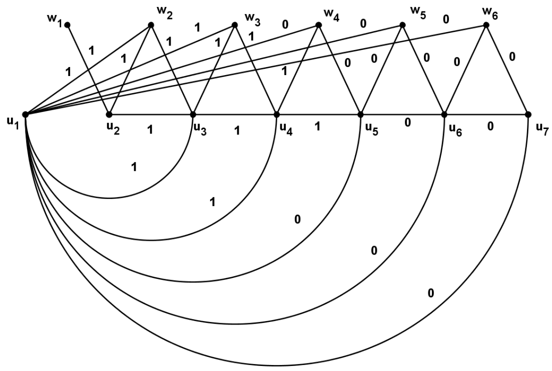

FIGURE 6. G_{u_1} obtained from T_7

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